A

PLEA FOR PURE SCIENCE:

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BEING

THE INAUGURAL LECTURE

AT THE OPENING OF THE

FACULTY OF SCIENCE,

IN

UNIVERSITY COLLEGE, LONDON,

OCTOBER 4TH, 1870.

BY

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LONDON:
PRINTED BY TAYLOR AND FRANCIS, RED LION COURT, FLEET STREET.
1870.

A PLEA FOR PURE SCIENCE.

Ladies and Gentlemen,

I propose in addressing you to-day to give an outline of the benefits which science confers upon mankind, and the process by which it does so. My object is practical. I want to lead you to a point of view from which you may best see and judge what is to be done in order to enable every individual to participate, as far as possible, in the benefits which science confers. In furtherance of this object it will be necessary to consider some matters which are not themselves scientific, but which are dependent upon the results of science; for the effects produced by an agency are seen upon surrounding things, and are estimated by the changes which it brings about in them.

Now, science has a powerful influence on the business of life, and, accordingly, we shall have to take account of business matters, and to notice what science does for them.

It must not be supposed that I use the term "business of life" in any narrow sense, although my illustrations will, for the sake of clearness, be taken from industrial life. The business of life of each individual is to do the various duties of his or her station; some duties relate directly to the production or interchange of useful materials of a special kind; some to monetary transactions, of which the success depends upon the general results of manufactures and trade.

A more general and fundamental duty, of which the

efficient discharge underlies most others, is to preserve and develope the bodily health by a due observance of the physical and other conditions which conduce to it; and many duties of a high order relate more directly to the physical or mental activity of man, or to the general direction of his labour. In short everybody has duties which bring him in contact with animated and with inanimate nature, and the efficiency with which he discharges them depends on his knowledge of the corresponding order of nature as taught by science.

It frequently happens that those who are aware of the deficiency of any existing system, and who see means by which that deficiency can be supplied, concentrate their attention so much on the circumstances which indicate the deficiency, and on the advantages which they expect to accrue from the adoption of the remedial measures, as to exaggerate their importance and to undervalue the existing system. At the same time others, knowing that much good is being done by the existing system, and that still more good might be done by its extension, overlook its inherent shortcomings, and desire to maintain it unchanged, while applying it more and more extensively.

The innovators look upon these latter as mere obstructives, and are in their turn considered as disturbers. Each party feels that its own views are true and useful, and seeing that the views of the other party are very different, jumps to the conclusion that they must be untrue and mischievous.

The history of human activity abounds with records of conflicts between parties differing from one another in the point of view from which they consider some one question.

But there is not a nobler proof of progress in human society than the change which is so steadily and rapidly taking place in the character of those conflicts.

The word toleration inadequately expresses the principle of the change; for it merely denotes the absence of the

envenomed hostility with which an opposite view of any important question was habitually treated by savage men, and is still sometimes treated by the less enlightened members of our community. We now know that it is useful to have a division of intellectual labour, each side of a question being studied and represented by the aid of the best abilities of particular individuals; and our truest conclusions and best practical results are arrived at by combining the partial and one-sided views thus elaborated.

The very excellence of our legislature results from the fact that it is composed of parties of men taking opposite views of the questions which come before it, their regulated conflict serving to promote a full consideration of each question. Her Majesty's Opposition has duties and responsibilities correlative with those of her Majesty's Government. So, likewise, in our courts of law the counsel for each party represent as fully and vigorously as they can the case of their clients; and they thus collect and arrange the materials for the decision.

One condition is, however, required for the safe working of any such system of the division of intellectual labour, viz. that each worker know and acknowledge the point of view at which he is placed and from which he sees, so that he may seek aid of the kind required for his work, and that his statements may not be liable to misinterpretation as advocating a view which they really oppose.

We thus not only wish men to take different sides of important questions, we also wish them to acknowledge publicly the side to which they respectively belong, in order that they may do their work as well as possible, and that other people may be able to use the results of their labours with safety.

Now there are in education two great natural parties, corresponding to the two most different points of view from which the preparation of any young person for his

career in life can be considered. I submit that the progress of education will be proportional to the consistency and completeness with which the functions of these two parties are systematized and developed.

The first step towards that object is to know and acknowledge their respective characteristics.

One party looks to the special duties for which a young person has to be prepared, and the material difficulties which he is expected to encounter. They see that the success and happiness of each individual are proportional to the efficiency with which he discharges the aggregate of the special duties of his station in life; and they accordingly recommend that each youth be placed in circumstances which may induce him to imitate accurately the doings of some one who is known to be successful in a station such as he is intended to occupy. The other party looks to the general qualifications which experience has shown to be most important for any success in life, and to the means by which they are most effectually acquired. They see that men who have been taught to understand and apply the best-known general principles, are able to master a given set of practical details with a facility and completeness which other men do not attain. They know that a general principle of nature is an instrument of thought applicable to the explanation of an infinite variety of phenomena, and they recommend that every one be placed in his youth somewhere where he may best learn such general principles. The first party takes little account of the development of the mental powers as a distinct object to be aimed at in education, the second attends but little to special business operations.

The former recommends special or technical instruction with a direct view to material success in a particular business, the direct aim of the latter is to educate and strengthen each individual mind. The essential differences between

them arise from the fact that they look at the question from opposite sides and respectively put forward what they see most clearly. But those who go into the question from the practical point of view, soon come to see the necessity of some scientific knowledge, and those who go into it from the side of theory gradually come to practical considerations. What is wanted is a system satisfying the requirements of both parties.

A purely practical apprenticeship or pupilage does lead a man to desire, and to some extent to obtain, a knowledge of scientific principles. He cannot get on in his practical operations without some such knowledge, and he manages to pick up bits of it, in proportion as the want of them is urgently felt, gradually increasing his store of general knowledge in after life.

On the other hand, those who have received instruction in general principles, accompanied by practice in the methods of their application to simple cases, have ample opportunities during their special pursuits in after life, for learning all the particulars of a business, and for improving its details.

The special men leave to chance the acquisition of scientific knowledge, and the training of the mind. The men of science do not take cognizance of the special conditions requisite for realizing success in each business. They observe and compare the means by which men attain the utmost usefulness in their practical pursuits, and perceive that the very great majority of such men have got certain habits of mind in common with one another, habits of mind which enable them to understand and control natural processes, in proportion as they become accurately and fully acquainted with the particulars of the processes in question.

Men of detail do not sufficiently appreciate the value and usefulness of ideas, or of general principles; and men

of science, who learn to understand and control things more and more by the aid of the laws of nature, are apt to expect that all improvements will result from the development and extension of their scientific methods of research, and not to do justice to the empirical considerations of practical expediency which are so essential to the realization of industrial success in the imperfect state of our scientific knowledge.

Having thus far sketched to you the outline of the characteristics of these two great parties, I propose now to describe some results of the arrangements recommended by them respectively: what the schools of science succeed in doing well in the way of giving preparation for the business of life, and what are the conditions most favourable to the success of that preparation; and, on the other hand, what the system of apprenticeship or professional pupilage effects, and how the benefits of such pupilage are most effectually secured.

A correct appreciation of the conditions requisite for theory and practice respectively, will suffice to show the natural order of a general system of education.

In illustration of a school of science I may be permitted to refer to our Faculty of Science in University College as that best known to me.

And, first of all, allow me to point out, that by instituting this Faculty of Science, the Council of University College has marked off a certain number of the College classes by giving them a general name suggestive of some important ideas.

Our Faculty is part of an establishment devoted to the pursuit of Learning, and each of the classes of which it is composed affords instruction in the doctrines and methods of its own particular part of science, with a view to accustom the mind to use well-established truths of nature for the discovery of other truths. The department of Learning denoted by the word Science, is dignified by the

academic title of Faculty without being severed from kindred subjects, with which many good offices are interchanged. It is here side by side with a Faculty of Arts and Laws, and with one of Medicine, while a Department of Fine Arts is at present in course of formation; so that those who here learn or teach science, form part of a little community containing men excelling in various degrees in the knowledge of languages, of literature, and in various other branches of intellectual culture.

It is worthy of note that in most of the science classes knowledge is obtained, not only through the medium of words, but partly also from observation of materials and of experiments. Thus, the lectures on Physics and on Chemistry afford verbal descriptions of things or of phenomena, accompanied, in many cases, by an examination of the things described. The relations of phenomena to one another are also frequently illustrated by experiment, as well as described in general terms by a law.

In like manner, instruction in Geology, Botany, Zoology, Physiology, &c., is illustrated by carefully selected specimens or experiments.

But that is not all; for the practical classes, which form an important and increasing portion of the system of instruction on many subjects of the Faculty, afford practice to each individual student in methods of experimental inquiry.

He there goes through for himself reasonings similar to those which he has heard in the lectures, and interrogates nature by the aid of the methods which he has there learned.

Under the guidance of the Professor he practices Bacon's precept, by working and thinking, then working again, and testing the truth of every anticipation by observation and experiment.

Some branches of science do not possess, in the same

degree as those above mentioned, the means of experimental illustration.

Thus, in Mathematics, the process of abstract reasoning is carried so far as to outstrip our methods of experimental illustration; and we find that by pursuing with rigid consistency the simple laws which regulate its operations, it arrives at methods of perfectly general application. Whenever we study any order of natural phenomena, we get to mathematical laws for their representation, in proportion as our knowledge becomes accurate and comprehensive.

One of the most remarkable of recently-discovered applications of Mathematics is to the forms of Logic; and it seems likely that the laws of thought will ere long be worked out still more fully in a mathematical form. Moreover, the study of the conditions of all correct reasoning has an obvious bearing on the advancement of science; while in Psychology the attempt is made to deal with the permanent facts of our mental nature.

Another subject included in our Faculty is Political Economy; for it has been shown that the general phenomena of the production and distribution of wealth in modern society, are amenable to natural laws as truly as the simpler phenomena of nature, and that it is as necessary for those who take part in operations affecting the production or distribution of wealth, to know the natural laws in accordance with which they must act, as for a chemist to know the natural laws of the formation of compounds, and of their distribution in the processes which he directs.

If we compare the things shown in science-classes and the experiments there performed with other things and operations, we see at once a difference which explains the principle upon which they have been selected or contrived. Their essential characteristic is simplicity. They are the things and operations which we understand best—things

which illustrate most clearly the known properties of matter—operations of which each particular is so accurately known that we can direct them with unerring certainty.

Not only is this so, but, in proportion as the system of instruction is perfected from year to year, this characteristic is more and more strikingly developed. Any new experiment which shows more clearly than others the working of an important natural law is gratefully accepted by the teacher of science, because he knows that its adoption will increase the usefulness of his teaching.

Among the subjects included in our Faculty there are, however, two which refer to particular classes of applications of scientific principles taught in the classes of pure science. I refer to Engineering and Architecture. I might perhaps describe such classes as connecting links between science and practice; for a student duly trained in scientific methods learns in them how to apply his scientific methods, to practical questions which present themselves in the respective professions. The leading particulars of the professional practice are taught him in a scientific spirit, and in his subsequent pupilage he learns the exact working particulars of his own branch of the profession as carried out by some one eminent individual.

The great aim and object of science is to systematize our knowledge; and the discovery of an idea which helps to arrange any considerable number of facts, in such a manner as to facilitate their apprehension, is the highest result of scientific work.

Thus the periodical disappearance of the sun, and the various positions in which it is seen from the surface of our earth, are facts which we understand by the aid of the idea that the earth is moving in a certain orbit round the sun whilst revolving on its own axis. We know that a piece of iron crumbles away into rust by prolonged ex-

posure to the air; that a burning taper wastes away and gradually disappears; that animal life would soon cease if the supply of fresh air were stopped. These and an infinite number of similar facts are explained by the idea that there is in air a substance called oxygen, which combines under suitable conditions with many other substances, forming compounds, some of which are solid like the rust of iron, some liquid, and others gaseous like the products of combustion of a taper or the chief products of respiration.

The idea of elements, as we now use it, serves to explain processes of chemical change, for we are able to look upon them all as consisting of combinations with one another, or separations from one another, of certain simple kinds of matter, like oxygen, iron, &c., of which we know upwards of sixty.

But the work of science does not stop at the discovery of ideas which explain the kind of result which we witness in any order of phenomena. Astronomers were not satisfied with the qualitative notion that the earth and other planets have certain regular movements of rotation and revolution. They measured the velocity and directions of those various movements, and by carefully comparing them with one another, found that the movements of each planet round the sun can be explained by the laws of Kepler, and that these in their turn follow from the more general law of Newton.

The law of gravitation is a model of scientific work, and its discovery is justly acknowledged to be one of the noblest triumphs ever achieved by science.

In like manner Chemists measured the quantities of elements which take part in combinations, and compared them with one another. They discovered in this manner the idea, that each element is composed of atoms, alike among themselves, but different from the atoms of which other elements consist.

The atomic theory has proved to be as trustworthy a guide to Chemists as the theory of gravitation is to Astronomers. Every accurate analysis yields results in accordance with it; and all numbers which do not agree with the atomic theory are found, on more careful investigation, to be erroneous.

The undulatory theory of light gives ideas by which we understand the phenomena of optics, and the development of that theory has given to optics its high scientific value.

Now, suppose that it were possible for a man to learn by heart the particulars of all the astronomical observations which had ever been made, and that he actually accomplished that feat, do you think that he would in that manner have mastered the science of astronomy?

A sort of living astronomical table he might be; but I think you would not call him an astronomer.

If, on the other hand, he observed accurately the position of a planet at several different times; if he recorded his observations in such a manner that they could be accurately compared with similar observations made by other persons; and if, from these particulars, he could calculate the orbit in which the planet moves round the sun, you would see that he understood the law of the planetary motions, and that he could apply it to the explanation of the observations which had been made, and to the anticipation of others.

Such knowledge of laws and power of applying it constitutes science.

Again, suppose some one to have acquired an empirical knowledge of chemical processes sufficient to enable him to perform brilliant and startling experiments, but that he did not describe the constitution of the substances which he employed, and did not explain the nature of the processes, we should look upon his performance rather in the light of conjuring tricks than of chemistry. It might

amuse, but it would not instruct us; and we should long to know the how, and, if possible, the why, of the marvellous effects which we had witnessed.

To any one possessing a clear and vigorous mind, the acquisition of an idea which helps to explain things is a source of intense pleasure. He feels that it enlarges the scope of his mind, and gives him new power; and when facts, previously unintelligible, are explained by the aid of such an idea, they immediately acquire vivid interest and special value to his mind; such facts seem to gain life by acquiring an intelligible place in the system of nature.

I believe that the triumphant feeling of the enlargement of his faculties which is experienced by a real student in the acquisition of any new law or principle of nature, is the most direct and vivid reward of his labours. The best and truest, as well as the most rapid progress in study, is made for the sake of that reward. Whoever has once enjoyed it, will gladly seize any opportunities of wrestling, as far as his powers permit, with new difficulties, and mastering new ideas.

It has been said that the happiness of an individual results from the due exercise of his various faculties, and this is surely not least true of the highest faculties of the mind; certainly those who have the power of understanding the wonders of nature, derive great happiness from learning to employ it. It is like the pleasure which a man of healthy and vigorous frame experiences in climbing a mountain peak, and in enjoying, in proportion as he rises, a wider and more commanding view of things below.

The study of science has been thought to promote scepticism; but I think it may be quite as truly and usefully described as replacing the wavering uncertainty of a sceptic by the confiding calmness of thorough conviction. Its higher development checks a disputatious tendency, and inclines us to believe that there must be some good in any con-

clusions which are valued by earnest though one-sided men, and to expect that their errors will be rectified by further investigation. Every partial truth is more or less distorted; and our knowledge of any one thing increases in accuracy in proportion as the thing is studied in relation to the general order of nature of which it forms part.

Again, while imparting just confidence in truths which are clearly proved, and in general principles which have shown themselves to be safe and trustworthy guides to the anticipation of natural phenomena, science teaches and necessitates a modest mistrust of oneself, by showing that even the most careful observer and reasoner is more liable to error than a body of similar men, who see the same thing from various points of view, and reason upon it accordingly. It also shows how small are even the most complete and perfect results of any one man's work, compared with the vast stock of knowledge accumulated by the labours of all, thus teaching gratitude to our fellow men, and admiration for their aggregate faculties.

Now, when we study the conditions under which science flourishes, and most effectually does the good which it has to do, we notice two of preeminent importance,—two conditions which are essential to the due success of efforts to transmit to the individuals of each successive generation the intellectual inheritance accumulated for their benefit, or to increase the amount of that inheritance by experiment and reasoning.

The first relates to order. The mind must begin with the simple, and rise gradually to the complex. It must not be disturbed in its efforts to understand natural phenomena, by the consideration of industrial operations unsuited to promote that object. Its best powers are none too great for the task before it, when exerting themselves under the most favourable conditions; and even the most powerful intellect finds ample scope for all its energies, in learning

the laws of Nature from the simple phenomena selected by Science, and in exercising itself in the application of that knowledge to experiments contrived for the sake of simplicity and accuracy.

Industrial applications of scientific principles are worked out with a very different view from that of aiding the mind to understand those principles, and from their very complexity are peculiarly ill-suited for that purpose.

The second circumstance is that the student of science be surrounded by men whose minds are earnestly devoted to the study, and who are so skilled in the methods of science, and imbued with its true spirit, as to afford models worthy of imitation. Many a good and useful lesson is unconsciously learnt, from the example of men whose lives and energies are systematically devoted to the study of pure truth, and whose pursuits are of a kind which succeed in proportion as they are more distinctly in accordance with its precepts.

In a little community composed of such members, there is an appreciative sympathy with all efforts directed towards the common object, which encourages each member to use his utmost exertions for its attainment.

It is the function of a University or College to combine these conditions for the pursuit of learning in its various branches and degrees, partly by excluding all disturbing influences, partly by maintaining the highest possible standard of earnest inquiry among its various members. I believe that it is a waste of time and energy for any student who can place himself under such favourable conditions to attempt to dispense with them. On the other hand, I know of nothing which the State can do for the cause of education with such certain benefit, as to supply the material conditions requisite for the efficiency of Universities and Colleges, in proportion as their active usefulness is seen to be impeded by the want of such aid.

Let us now consider the usual results of the system of special professional pupilage, as practised by any one who endeavours simply to imitate the means taken by some one successful man, and who, without any scientific preparation, endeavours to copy what his master does or what is done by those in his employment.

Anyone who carefully imitates the various operations required for success in a particular business, and in such a manner as to satisfy an efficient manager, learns the particulars of them with an accuracy and completeness unattainable by any other process. He sees, and does in pieces, what is necessary in order to secure the desired result of profit under the special conditions of that individual business. A vast variety of arrangements and precautions, suggested for the most part by empirical observation, are combined for that one object. The manager judges of each part of his processes by the test of expediency; if it increases his profits he approves of it without reference to any other consideration.

When the pupil becomes in his turn a master, he endeavours by careful supervision to ensure the due discharge of their respective functions by all his workmen, and to keep the whole system of operations going on according to the plans which he had learnt. If the business returns good profits he probably extends his operations, as far as his capital and energies enable him to do so, under conditions similar to those which were found profitable.

A great amount of work is being done in this kind of way, and there is doubtless scope for much more of it. In nearly every business we see profits made by men of industrious painstaking habits, who adopt and continue for a while some system which they have seen at work, without attempting more than to imitate those who have succeeded in the business.

But it often happens that a man learns thoroughly the

particulars of a business, as practised in some one successful case, and although he has sufficient capital and industrious habits, fails to realize similar results elsewhere.

For instance, he has learnt and practiced the management of a particular farm, and then takes a lease of one in another district. He purchases implements exactly similar to those which he has been using, and gets sheep and cattle of the same breeds. He adopts the same rotation of crops, and spares no pains to make everything go on precisely in the same way as that to which he has been accustomed.

His first year is unprofitable; but he looks forward hopefully to better results, when things will have got into better working order. But the second and third year only bring more losses, and he is ultimately compelled to give up the farm.

The next tenant is perhaps a man who has learnt the management of an adjoining farm, which happened to be in size, in soil, &c. very much like it. He uses ploughs and other implements which have been found to suit the soil, and gets breeds of sheep and cattle which thrive in that part of the country. He adopts the same rotation of crops and system of manuring which is customary in that district, and carefully imitates what he had seen to succeed, under conditions similar to his own. The result is that he goes on steadily year after year making a fair profit.

Both of these men were mere servile imitators of what they had seen, and both had been taught to believe that a practical man ought to be nothing more, and that all theories are dangerous. Yet one failed while the other succeeded. We ought not to be surprised at the failure of the one, so much as at the success of the other, which was due to the exceptional circumstance, of his finding a farm which admitted of being profitably managed upon exactly the same system.

Those who have attentively observed the conditions of success in manufacturing arts, know that an understanding of the processes is essential to those who undertake to direct them, and that they must be supplied with ideas for that purpose.

The question is thus raised, What are the intellectual habits required for the conduct of industrial operations? and further, How are they best acquired?

An iron-master uses air, coal, iron-ore, and limestone, as raw materials, and by their action on one another, under certain conditions maintained in his blast-furnace by the action of machinery under the direction of workmen, he makes hot gases, slag, and pig-iron.

To conduct his business well, he must understand the physical and chemical changes which take place in the furnace, and the manner in which they are affected by the quality and proportions of his materials. He must understand the action of the machinery which he employs. He must understand how "to buy in the cheapest and sell in the dearest market," and many other things besides these.

The more complex materials which are employed in the operations of dyeing or of fermentation, undergo changes more various and more difficult of comprehension; and we accordingly find that those operations are subject to greater variations, and their results to more uncertainty. But these materials differ chiefly by their greater complexity from those which we understand more fully. Their properties and changes are subject to the same general laws, and are understood in proportion as we are able to apply these laws to them.

The healing art in its various divisions is of a still higher and more difficult nature, not merely because it directly relates to the noblest and most complex of known organic beings, but also because it demands more varied and more extensive qualifications on the part of those who practice it.

Now we usually find that those who conduct a particular set of processes, are conscious of the necessity of understanding them, and, in proportion to their activity of mind, they take such means as are within their reach of obtaining a knowledge of the principles upon which the processes depend. Their object being to understand the processes which they have to direct, they very naturally ask for direct aid for that special purpose. A brewer asks to be taught the Chemistry of brewing. An iron-master wishes to learn the Chemistry of iron-making. A ship-builder imagines that he might be taught the calculations required for that business without the trouble of studying the scientific principles on which those calculations depend.

Now the explanation of any chemical or mechanical arrangement or contrivance is supplied by certain simple general principles which are explained and illustrated in the manner most convenient for their easy acquisition and practice in certain departments of science called Chemistry and Mechanics; and those who have been taught to apply those principles to simple examples, are able to understand and direct complicated operations and machines with a facility and accuracy unattainable by others.

Those who attempt to learn at once the application of scientific principles to the complex processes which occur in manufacturing arts are trying to run before they have learned to walk.

It would be a cruel deception to encourage such an attempt. Many of them, however, do manage by their individual exertions to acquire some knowledge of scientific principles, and to get a part of what they want under peculiarly difficult and unfavourable conditions.

But although a considerable amount of good and useful work is done by men whose intellectual excellences consist mainly in the habit of vigorously applying to a particular practical purpose a limited stock of ideas which they

find near at hand, there are other qualities and powers which make themselves felt, and which accordingly claim our attention.

There are men capable of modifying a system when new circumstances arise—of making arrangements to meet new wants in proportion as they are felt—and even of anticipating wants by devising new products, or better kinds of an old product.

There are men also who penetrate beyond the knowledge given to them of the processes of a manufacture, who make new observations and experiments relating to them, and who bring to bear on them knowledge acquired in other fields of work, or inventions which had been made for other purposes. The result of their influence is, that any manufacturer who keeps to his old system without gradual improvement soon gets left behind. He may not realize this result for a while, but it never fails to show itself in time. It does not do to stand still, while others around us are moving on. Every industrial art is steadily undergoing change and development, the most efficient and active men of business drawing away the profits from the feeble and inert.

It must not, moreover, be supposed that this state of things is due to a mere accident of the present time or place. It results from a fundamental law of life which regulates the development of the various functions of animated beings. The discovery of this law by the master-mind of our age is probably one of the greatest steps ever made in our study of the order of nature, and marks an era in the history of the human mind. If we consider it in its most general bearings, we might call it the Law of Progress. It teaches us that each generation of animated beings consists of individuals who inherit most of the peculiarities of organization of the parent-stock, but each of whom differs slightly in some particulars from its

parents. Some individuals have peculiarities which enable them to excel in the struggle for subsistence, and they manifest this superiority by thriving and drawing to themselves nourishment to the detriment of those who are less favourably organized. But the descendants of well-organized individuals inherit, for the most part, the excellences of their parents, some in a greater, others in a smaller degree; and the average of them is better than the average descendants of ill-organized individuals, and excels them in the struggle for subsistence, thereby maintaining the excellence which characterized their parents. Again, while each successive generation inherits the average qualities of its predecessors, it inherits, in like manner, the struggle for subsistence, the well-organized thriving better than the rest. From time to time an individual appears possessing the very excellences of his parents in a still greater degree than they; his existence is the germ of progress, and his success in the struggle for subsistence is the process which constitutes the development of progress.

It must be observed that I here use the term excellence to denote the peculiarities, whatever they may be, which enable an individual to excel others in the struggle for subsistence, under the particular conditions in which they are placed.

Now an improvement once established in a particular business works its own way by a process similar to that by which an improved variety of a plant or animal is developed by natural selection. It may consist in improving some article of commerce, or in producing some useful substance not previously made. It may consist in making some product more economically than heretofore by the introduction of better arrangements or of labour-saving machinery. Those who adopt it will undersell the others, and sooner or later drive them out of the market. Such an improvement works its way surely, though very often

slowly, owing to ignorance on the part of purchasers of what they ought to expect.

Of course many alterations in industrial processes are proposed on erroneous grounds, and are not really improvements, as their originators imagine. Some are proposed before their time, in fact under conditions in which their introduction would not be advantageous. But when allowance is made for the necessary variety of circumstances, it will be seen that by the natural working of society every variety of business is subject to this same law of progress.

Efficient and improving men of business get more and more the command of the markets, whilst those who cannot advance with their time gradually get pushed out, and are known by their complaint that "business is not as good as it used to be."

Now the mental qualifications which enable a man of business to contribute to progress in the particular industrial operations which he conducts, may be described by one word:—they are the qualifications of an experimentalist.

The introduction of any change in a system of industrial operations is an experiment; and whoever manages it ought to know that it is one, and to conduct it in such a manner as to make it a true and good experiment.

Suppose, for instance, that the change consists in introducing some labour-saving machine which is being used with advantage by others in the same business. The circumstances of the man who wishes to adopt it are different in many respects from those in which the machine has been tried. His workpeople have different habits and ideas, and are not equally qualified to undertake the more skilled labour of managing a machine. His raw materials are not obtained in the same state of preparation, or his capital may not be as great as that of others.

He gets the most accurate and complete information in

his power respecting the conditions under which the machine has been hitherto used, and compares them with the conditions under which he would use it. He studies with especial care the conditions in which his experiment will differ from those already tried; in order to form an opinion how far they would be likely to influence the result. He contrives means for modifying the unfavourable conditions, and for increasing the influence of those which appear to be favourable; and with such a plan in his mind he decides upon trying the machine on a scale as small as seems practicable. The trial confirms some of his anticipations, but probably fails in some respects to realize what he expected. He examines carefully the particulars of the cases of failure, and tries to find out the conditions upon which they depend; thus probably discovering peculiarities in the machine of which he was not aware.

The difficulties which arise in the course of such trial would discourage some people, but they only stimulate our true experimenter to fresh exertions. Having undertaken to try whether the machine can be advantageously employed by him, he is determined that his best exertions shall not be wanting to make the experiment give a clear and decisive result. No doubt the labour and money which he has expended on the experiment strengthen his motives for wishing that the machine may answer; but after weighing carefully the results of a full and fair trial, his business is to balance them carefully and truthfully in his mind, and to judge whether or not they afford grounds for finally adopting the machine.

Questions such as these are of very common occurrence, and are among the simplest which an improving manufacturer has to decide experimentally; but there are many of a kind in which he has no close analogy to guide him. Perhaps a new raw material, such as esparto or jute, is introduced into the markets, and is thought likely to serve

as an economical substitute for some other material now in use. But the new material has to be tried; and those who first find out by experiment how it can be profitably employed, have a more difficult task than those who subsequently imitate their results, and a task which involves more experimental originality.

There are also many improvements which are required by the occasional failure of a process, entailing loss on the manufacturer, or variations in quality, causing dissatisfaction on the part of the purchasers, and which are entirely beyond the scope of the ideas which have found application in that particular business.

For instance, a dyer sometimes fails to give the desired tint to his cloth, a brewer sometimes cannot get his wort to ferment properly, a manufacturer of steel does not produce the material of sufficiently uniform quality to enable the tool-maker to impart an equal temper to his tools. Such a difficulty affords full scope for the exertions of a man who is skilled in the doctrines and methods of experimental science, and who also knows accurately the working of the process. It differs from the experimental problems which are taught as exercises in Science classes, chiefly by its much greater complexity and difficulty.

The most striking and characteristic cases of progress in the industrial arts are, however, those in which the improvement comes from without, from experimentalists not previously engaged in the business. Take, for instance, the discovery of the mauve colour from coal-tar, a discovery which may be said to have opened up a new branch of industry. It was not a colour-maker who tried to get such a colour, and at last hit upon a method of preparing and manufacturing it. It was a young chemist, working in a laboratory devoted to experimental research; a laboratory justly celebrated for the success of those engaged in it in investigating the combining forces of matter, and for ap-

plying such knowledge to the preparation of new compounds; and the experiments by which the mauve dye was made on a small scale, were only a prelude to the experiments which led to establishing a process for its profitable manufacture.

Or take the two other most remarkable industrial novelties which have appeared of late years, viz. Siemens's regenerative furnaces, and the Bessemer process of decarbonizing iron. Each of these inventions is the result of a long and laborious series of experiments conducted under the guidance of scientific principles and scientific methods.

Now I suspect that some of you think I am proving too much, that I am laying down the principle that all men of business should be experimental philosophers, remarkable for their thinking powers. There could not be a greater mistake. True it is that they must have knowledge of things and principles, very clear ideas, and that they must be able to use their knowledge of these things and principles for the purpose of bringing about special results. In fact they must have a knowledge of the laws of nature, and skill in the methods of applying that knowledge to experimental purposes. Their power of bringing about the material results from which they derive profit is proportional (other things equal) to the amount of such knowledge and skill which they possess.

But their duty is to apply their knowledge of general principles and experimental methods to special practical purposes, not to extend and create such knowledge, or to teach others how to extend or even to use it. A great general requires the best instruments of destruction which can be used by his troops, but it is not his business to invent or to manufacture them. He does far better to leave that work to others, and to concentrate all his energies on the arrangements for the effectual application

of the guns, &c. The multiplicity of details which a general needs to know and to arrange systematically, in order to ensure favourable conditions for success, is so enormous that the best of heads finds ample scope for its exertions in perfecting the application of existing weapons to his purpose.

In like manner the business of improving and manufacturing implements of war involves the knowledge of a variety of circumstances sufficiently numerous and sufficiently difficult to engross the undivided energies of able and vigorous men.

The necessity of the division of labour for perfecting its results, and for economising human power, is now generally admitted in principle; and yet it is a remarkable fact, that the most general and the most important of all the applications of that principle is commonly overlooked and disregarded.

I believe there is no case of the division of labour so important for the due success of the respective operations as the division between the labour of theory and the labour of practice. The labour of investigating nature and of teaching to others the knowledge so acquired, serves to endow mankind with true and useful ideas; while the labour of producing or distributing useful things conduces to wealth; and the due success of those operations requires that each one be consciously directed to its real end, under the conditions most favourable to its full success.

The workers in Science use the products of the industrial arts, and derive incalculable advantages from the improvements which take place in material products.

On the other hand those who direct industrial processes use the ideas which Science furnishes and the experimental methods which she establishes. Each class of workers is able to improve its own efficiency in proportion as it gets better and better supplies from the other party.

It is the boast of the English that they are a practical

people. Some persons are apt to interpret the term as implying a disinclination for theory; yet nothing is so unpractical as ignorance, and it can hardly be considered practical to learn imperfectly what has to be learnt. If scientific principles and methods are needed for the business of life, surely the practical plan is to get them by the system which is known to be most effectual for their acquisition.

If it be admitted that Science teaches the general order of Nature, and that a knowledge of its truths is needed by those who wish to understand and control any particular set of natural phenomena, it will, I think, hardly be denied that the study of Science ought to precede the special training to a business.

I will not attempt to add to this imperfect outline of the general uses of Science any description of the particular measures which suggest themselves as best suited to promote the development of a national system of truly general education. It may safely be affirmed that the first step towards anything worthy of such a designation must be the recognition by the State of pure Science as an essential element of national greatness and progress; and if the preceding remarks were to lead you to see the necessity of that step, their object would be attained.

THE END.